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The Spatial and Temporal Distributions and Thermodynamic Characteristics of Tornadoes in Mississippi

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THE SPATIAL AND TEMPORAL DISTRIBUTIONS AND THERMODYNAMIC CHARACTERISTICS OF TORNADOES IN MISSISSIPPI

By

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The vast majority of severe storm and tornado research is conducted in the natural laboratory of the Great Plains region of the United States. As a result, much of the knowledge and technology applied to storm forecasting is developed in the Great Plains environment. However, it has been shown that there is a maximum of strong and violent tornadoes in the region extending from Arkansas eastward into Alabama. In addition, various researchers have found strong severe storm thermodynamic signatures unique to regions such as the Northeast and Mid-Atlantic. This study has analyzed five decades of tornado data for the state of Mississippi. Thermodynamic results indicate that Mississippi has a tornado environment distinctly different than that of the Great Plains. The spatial distribution of the tornado events also indicates that mesoscale processes between the Earth's surface and the lower troposphere may play a significant role in determining the genesis location of violent tornadoes in the historical Delta region of Mississippi. It is anticipated that an

understanding of environments unique to Mississippi tornadoes will lead to better forecasts and more comprehensive storm analysis, which will ultimately save lives and property.

ACKNOWLEDGEMENTS

I would like to express my thanks to my committee members, Dr. Michael Brown , Dr. Charles Wax, and Dr. John Rodgers, for their help in completing this project. I would also like to thank my husband, Jonathan, for all of his help and support.

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INTRODUCTION

Introduction

The state of Mississippi ranked number one for tornado related deaths per million people with a total of one hundred and sixty-six deaths between the years of 1953 and 1995. For the same time span the state ranked number two for total tornado related deaths with three hundred and sixty-nine deaths. For the same time period Mississippi ranked fourth for the number of killer tornadoes with fifty-five, and eighth for the number of annual tornadoes per ten thousand square miles with about five (Grazulis, 1995).

Even though Mississippi ranks high in these categories, the majority of tornado research is performed in the Great Plains region of the United States. Recent studies suggest that there may be distinct regional differences in the environments in which tornadic storms develop (Davis et al., 1997). Therefore, it is imperative that we learn more about the thermodynamic environments associated with tornadoes in the Deep South and specifically Mississippi. Identifying and understanding the processes related to the spatial distribution of these storms will also aid in the more accurate forecasting of tornadoes within the state.

During the course of this study, point data will be plotted by latitude and longitude for each tornado that occurred in the state of Mississippi from 1950 to 2000 to determine if any spatial patterns or clusters exist. The thermodynamic structure of the atmosphere for a representative sample of tornado event locations will also be evaluated in order to determine mean values of critical forecasting indices for Mississippi.

Through this study, threshold values for specific thermodynamic indices will be determined. During future severe weather threats the atmosphere can be evaluated with respect to these threshold values and a determination of whether or not the atmosphere is favorable for the development of tornadoes in Mississippi can be made. Ideally, this will allow more warning time for the public, and ultimately help save lives.

Hypotheses and Objectives

Hypotheses:

- Tornadic storms in Mississippi are associated with environments significantly different from the Great Plains region.
- The spatial distribution of tornadoes in Mississippi exhibits a clustered pattern.

Objectives:

- Analyze thermodynamic properties of Mississippi tornadoes.
- Develop index threshold values unique to tornadoes in Mississippi.
- Develop a severe weather check sheet for Mississippi tornadoes.
- Determine if tornadoes exhibit a clustered pattern by performing a cluster analysis on the spatial distribution of tornado events.

One anticipates that once these objectives have been met, a determination through a skew-T, Log-P analysis if the synoptic scale and mesoscale environments present a threat of producing tornadoes, and how strong the tornadoes may be.

Chapter II

REVIEW OF LITERATURE

Literature Review

Much of the research concerning tornadoes and environments related to tornado development focus on the Great Plains region of the United States (Leathers, 1993). Figure 2.1 shows the typical environment for the formation of Great Plains tornadoes. A southerly low-level jet stream advects moisture-rich air from subtropical regions to provide the basic fuel for convection. A southwesterly flow provides a capping inversion to discourage the premature release of convective energy and squall lines become intense ahead of the cold front. The source region for this southwesterly flow is generally drier air from the southwest United States and Mexico that does not promote lifting. The westerly polar jet enhances upper-level divergence in the upper troposphere, which in turn enhances lower-level convergence and uplift.

There is evidence that tornado environments differ in various regions of the country. Leathers (1993) argues that the Northeast United States should not be overlooked as a tornado risk. Even a few weaker tornadoes could do a lot of damage as a result of the large population density in this region of the country. Davis et al. (1997) found that most conceptual models of the synoptic conditions associated with tornadoes are based upon conditions associated with tornadoes in the Great Plains

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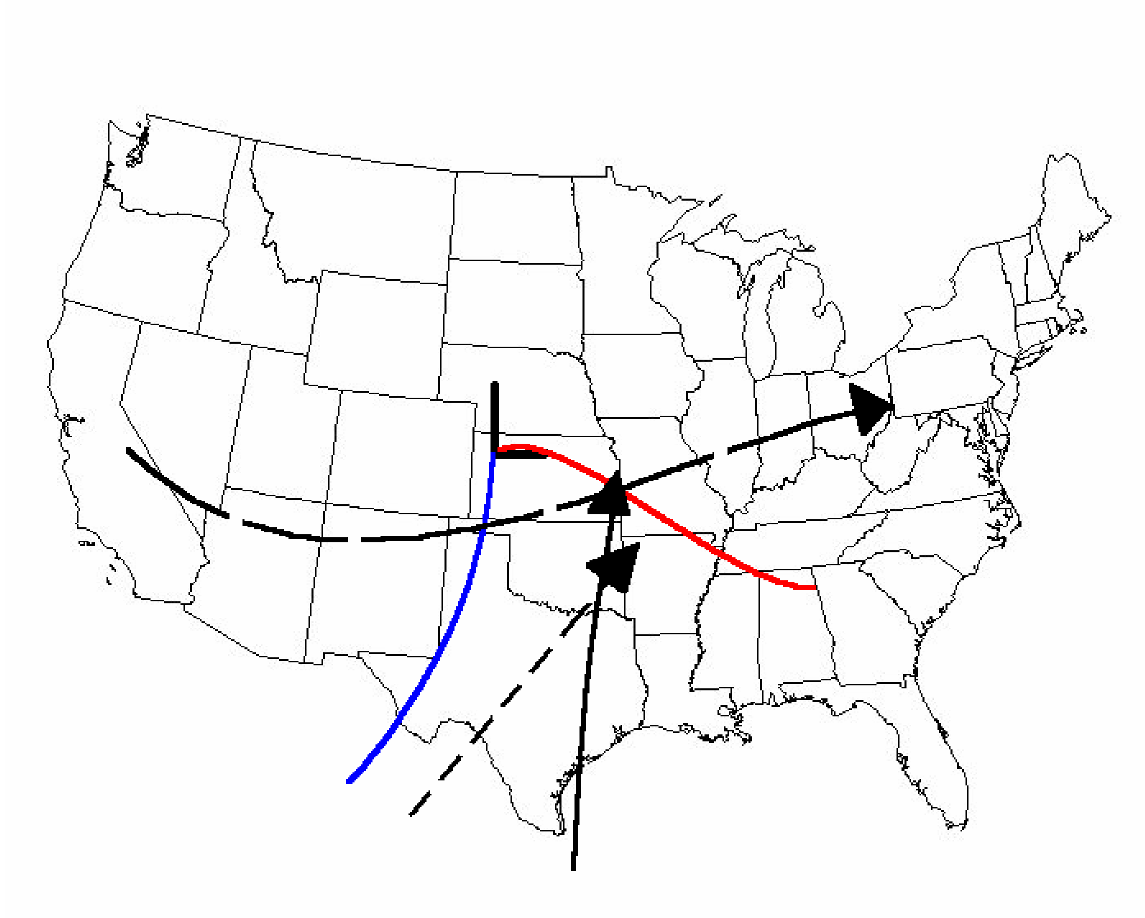

Figure 2.1 Typical environment for the formation of Great Plains tornadoes

region of the United States. They go on to suggest that different synoptic conditions are responsible for the formation of tornadoes in different regions of the country, and these conditions may vary significantly from one region to another.

However, “according to William Sammler, Warning Coordination Meteorologist at the Wakefield, Virginia National Weather Service Office, ‘The parameters used in forecasting severe thunderstorms, and the subsequent issuance of watches, are basically the same regardless of the geographical location, despite some significant differences between severe weather in the Plains and severe weather along and east of the Appalachians.’ A better understanding of these differences could ultimately lead to improvements in tornado forecasting on a region-specific basis” (Davis et al., 1997). A more accurate forecasting tool for tornadoes in the Southeast United States, specifically Mississippi, is exactly what this research will accomplish.

Johns (1984) drew several conclusions on how parameters differ regionally with tornadoes that form under a northwest flow. He describes that in the low-levels of the atmosphere, temperatures in the Northern Plains and Upper Mississippi Valley region are about three degrees Celsius lower than other regions in the United States. These regions also experience a higher percentage of nocturnal tornado outbreaks. Dew points in the Plains states tend to be lower as a result of the higher elevations. One parameter that seems to differ substantially is wind direction and shear. The Plains states outbreaks are often associated with a South-southeasterly wind in the low levels that veers with increasing height. As you travel farther east, winds do not tend to veer as much with increasing height but do veer with increasing horizontal distance. Williams (1976) similarly noted regional differences in wind patterns.

Most surface winds related to tornadoes are from the South or Southwest when East of the Mississippi River. However, most surface winds related to tornadoes are from the South-southeast when West of the Mississippi River (Figures 2.2 and 2.3).

Varying topography is yet another reason to further study different regions in the United States and how this topography affects the parameters associated with tornado formation. Kelly et al. (1985) looked at severe weather phenomenon by region and found that the Southeast United States is the preferred area for many types of weather events. For example, Kelly et al. (1985) found a maximum of hail occurrence in Alabama. The Southeast ranks number three for both severe wind occurrence and ranks number two for overall severe weather activity (Figures 2.4 and 2.5). The National Severe Storms Forecast Center computed the average annual migration of tornado activity, finding that tornadoes in the Southeast are generally early and late in the calendar year.

A common theme found in tornado climatology is a distinct regional difference in the tornadic environment. For example, Johns (1982) found that initiation times of severe weather outbreaks vary regionally, and generally initiation times in the Southern Plains are diurnally polarized. This suggests that diurnal heating is necessary in the Southern Plains region for the initiation of the severe weather outbreaks. Johns also found differences in the length of time a tornado outbreak duration. Outbreaks generally survive ten hours in the Upper Mississippi Valley and are a little shorter in the Southern Plains, lasting approximately eight hours. Kelly et al. (1978) also found different regional characteristics of tornadoes. There are two main violent tornado maxima, one in Arkansas and the other in

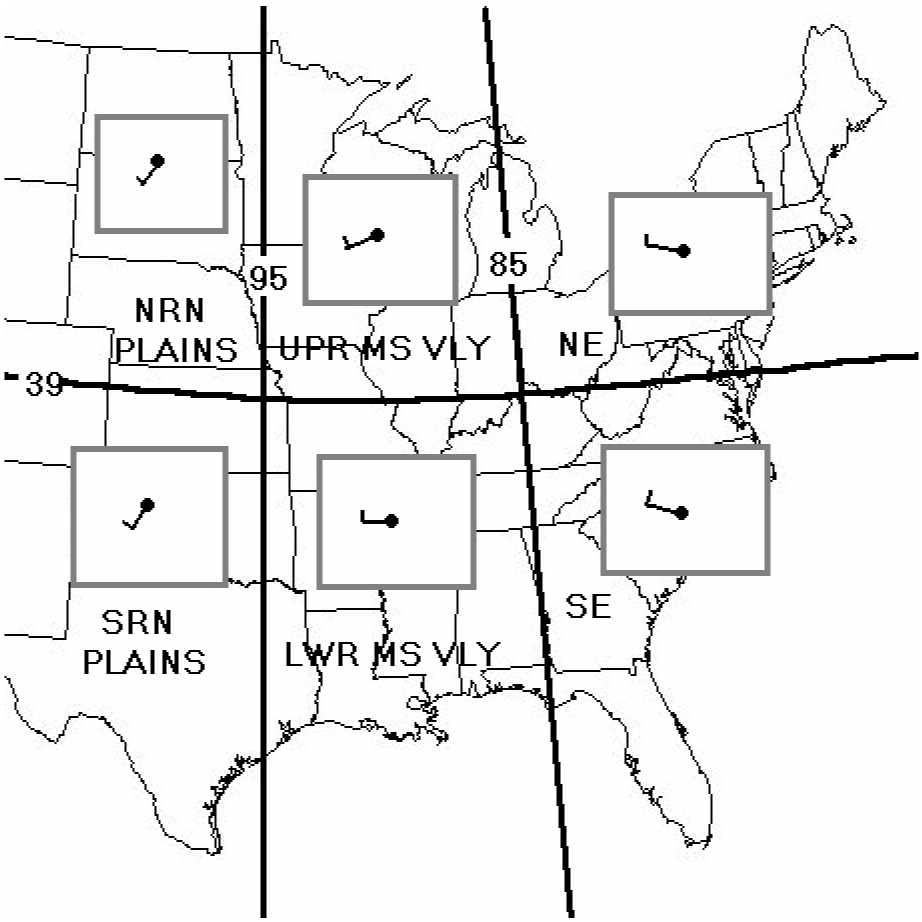

Figure 2.2 850mb winds related to tornadoes, after Johns, 1984

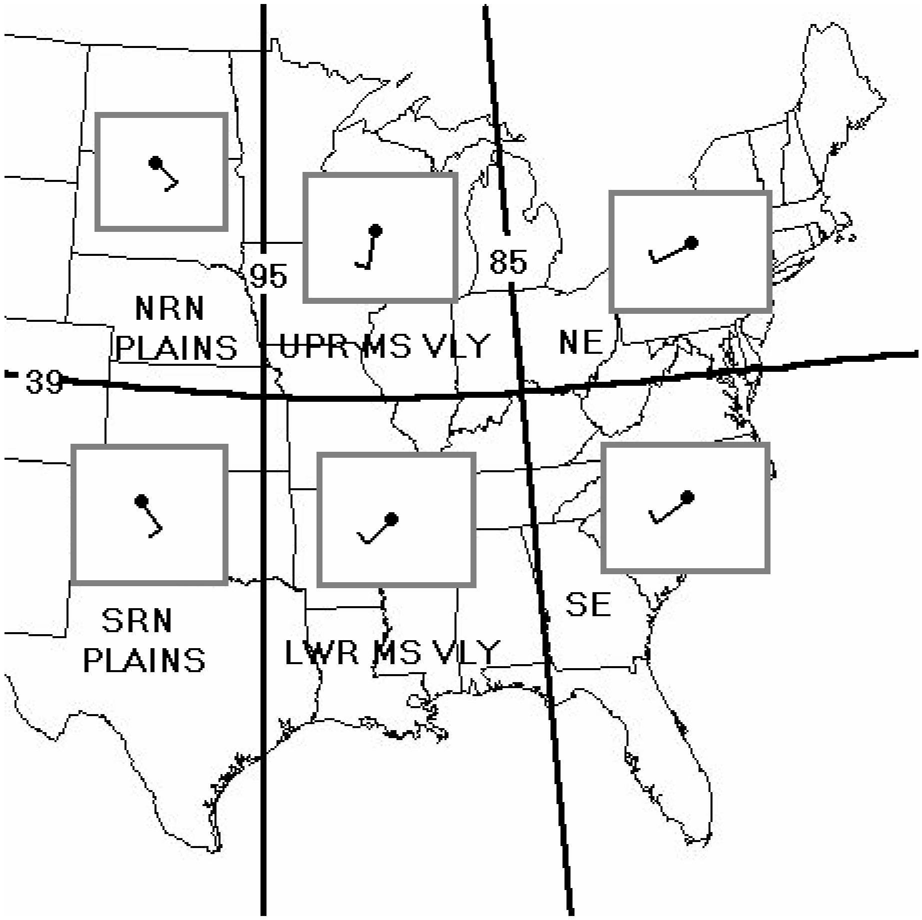

Figure 2.3 Surface winds related to tornadoes, after Johns, 1984

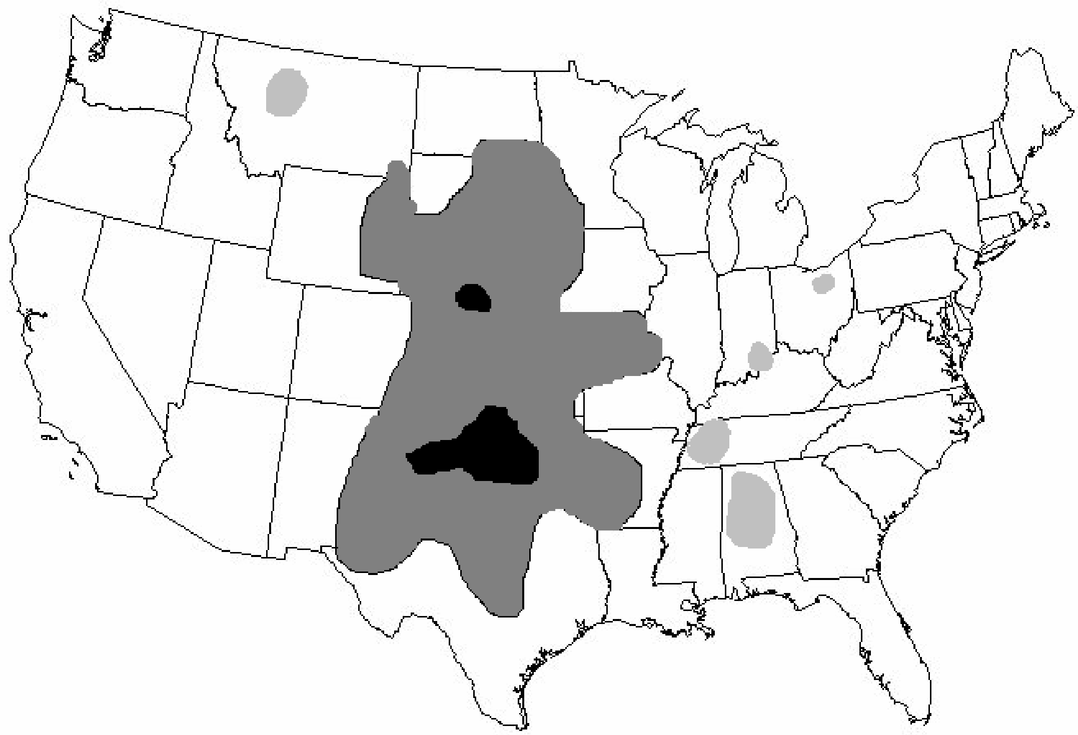

Figure 2.4 Severe Wind Occurrence, after Kelly et al., 1985

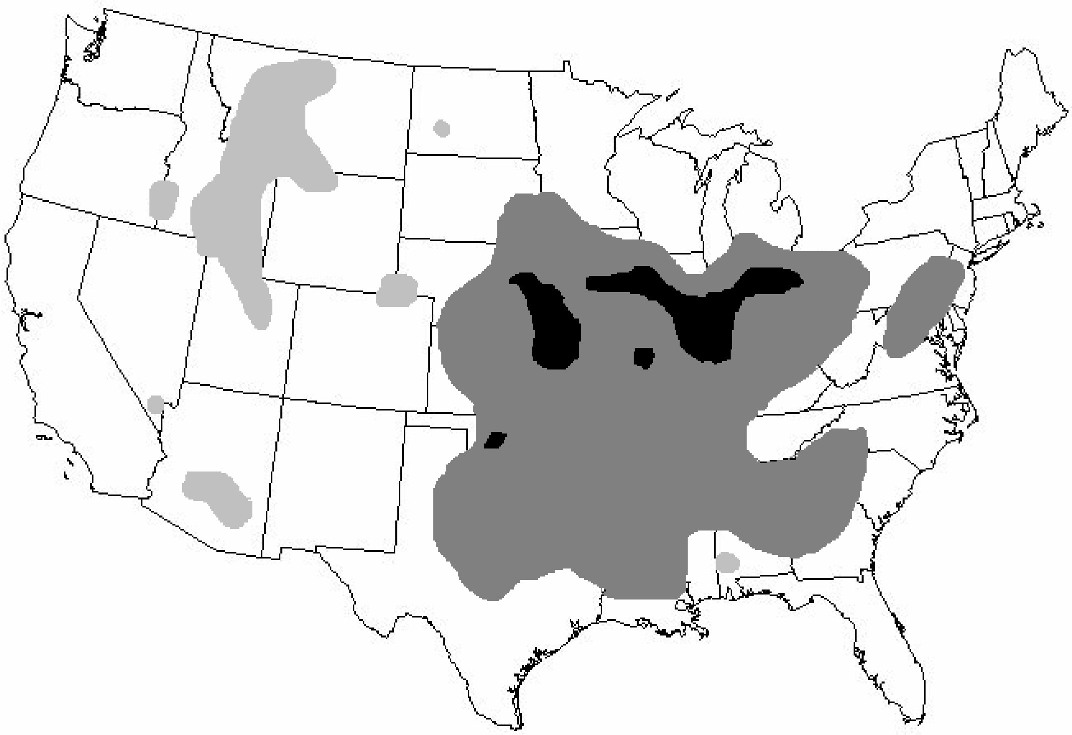

Figure 2.5 Severe Weather Activity, after Kelly et al., 1985

Alabama, which cannot be attributed to tornado outbreaks (Figure 2.6). This leads to speculation that there may be a regionally distinct factor related to the violent tornadoes in these southeastern regions.

Only 2.3% of all tornadoes are violent but they cause 68% of the deaths. Kelly et al. (1978) suggest that these two regions are simply too small to draw any significant conclusions. Regardless, statistics show that this region warrants further investigation. Figure 2.7 indicates that Louisiana and Mississippi have a maximum for long-path tornadoes. This could be a result of an abundance of low-level moisture from the Gulf of Mexico in this region feeding the storm systems, and therefore extending their lifetime and path length. About twenty-five percent of long-path tornadoes are violent, and to reiterate, violent tornadoes cause the majority of deaths, re-emphasizing the need to further study the southeastern United States.

Furthermore, Johns (1982) showed that there is also a distinct difference in the timing of tornadoes in the Southeast as compared to the Midwest and Great Plains. The Midwest and Great Plains are similar in that the peak tornado occurrence is in the late afternoon hours just before sunset. The Southeast has two daily peaks, in the late afternoon, and the other just after sunrise. The maximum around sunrise is unique to the Southeast. Also, severe weather season in the Southern Plains and Gulf Coast is primarily in the spring (March to May) whereas severe weather season in the majority of the rest of the country is isolated to the summer season. The Southeast also has a second maximum of severe storm activity, large hail, damaging winds, and tornadoes, which occurs in the late fall. The Southeast is the only region that experiences this secondary maximum. Along with this difference in severe weather

Figure 2.6 Violent tornado maxima, after Kelly et al., 1978

Figure 2.7 Long path tornado maxima, after Kelly et al., 1978

season comes a difference in severe weather related damage. The farther South you travel towards the Gulf Coast, wind damage reports occur earlier in the day.

An additional study by Showalter (1953) focuses on severe storms in southern California. Severe storms in this area are rare, but the author saw a need to better forecast such storms when they do occur. Showalter devised a Stability Index Computation Chart, which is used as a simple and fast checklist of the atmosphere to evaluate the potential for severe storms. He then devised a Tornado Index to be used as an aid in forecasting the possibility of tornadoes in this area. This type of output is what is expected from this research, focusing on the characteristics of tornadoes and synoptic conditions associated with tornado occurrences in Mississippi.

Davis et al. (1997) hypothesized that air mass types and synoptic conditions are different for Virginia tornadoes than for Great Plains tornadoes, and therefore different threshold values of severe weather indices should be used in their forecasting. The same hypothesis may be true for Mississippi, and by using the adjusted threshold values of severe weather indices, more accurately forecast tornado occurrences may be possible in the state.

In "Thunderstorms and Tornadoes of February 1, 1955", Jean Lee (1955) describes a tornado outbreak that swept across the northern part of Mississippi.

> One of the most death-dealing series of convective storms of the last few years occurred during the afternoon and evening of February 1, 1955. This series of severe local storms, accompanied by tornadoes, destructive winds, hail, and heavy rain, first struck near Marianna, Arkansas, at 1400 CST, roared through Commerce Landing, Mississippi, across northern Mississippi and on to near Huntsville, Alabama, where the system eventually dissipated around 1830 CST. Most of the injuries and fatalities caused by these storms occurred in northern Mississippi where over one-hundred twenty-five persons were injured and twenty-three other persons – mostly school children – were killed (Lee, 1955)."

Results of the research may go beyond improvements in forecasting methods. In "Tornado Probabilities", Thom (1963) was asked by an insurance company "to develop a system of limiting the loss from a single tornado in a given region for the purpose of preventing liabilities from exceeding reserve funds" in an area of Iowa. The author discusses the directional frequency and path length characteristics of tornadoes in this area and the probability of a tornado striking a specific point. Using this information he devises a directed standard path for the company. Using these standard path and probability statistics, the company could total the amount of liabilities within each tornado swath and if the amount exceeded the company's reserves, other insurance companies could insure the excess cost. This is just one example of the many uses of this study on Mississippi tornadoes.

Chapter III

DATA AND METHODS

Study Region and Study Period

Tornadoes in the state of Mississippi need to be studied because most tornado research is performed in the Great Plains region of the United States, even though research such as Davis et al. (1997) has suggested that there are distinct regional differences in the environments in which tornadic storms develop. Also, Mississippi leads the nation in tornado related deaths with a total of one hundred and sixty-six deaths per million people between the years of 1953 and 1995 (Grazulis, 1995). The years 1950 to 2000 were chosen because thermodynamic data and tornado path information are available for this time period. Data reliability will be analyzed case by case, but it is anticipated that the accuracy of both tornado and thermodynamic data will improve with time because weather instrumentation and public awareness has improved with time. There is considerably less reliable data prior to 1960, and most records of tornadoes from 2000 to the current time are incomplete. Therefore, each tornado will be plotted from the entire period (1950-2000), but analysis of the thermodynamic variables will be carried out on only ten percent of the tornado data set from 1958-2000. Thermodynamic analysis of ten percent of the data set will be statistically sound, given the large number of data points. Also, selecting a reduced number of cases makes this part of the study more manageable, due to the complexity of thermodynamic analyses and the large amount of data needed for each case.

Tornado Data

A total of 1387 tornadoes documented in the state of Mississippi from 1950 to 2000 were studied. Almost an entire year was needed to collect all of the information needed for each of these tornado events. The data compiled includes the Mississippi county in which each tornado occurred, the date, time, F-scale rating, number of deaths, number of injuries, property damage (in dollars), path length, path width, beginning latitude and longitude and ending latitude and longitude of each tornado from 1950 to 2000 (Table 3.1). These data were obtained from the National Climate Data Center (NCDC).

Thermodynamic Data

Temporal and spatial considerations were used for determining the location and time of radiosonde data for use in the selective thermodynamic analysis for ten percent of the tornado database. Thermodynamic data are available through Radiosonde Data of North America 1946-1996, provided by NCDC on CD. Recent data is available on the World Wide Web on NOAA's web site. Once the thermodynamic data were compiled, descriptive statistics of specific indices were calculated (Table 3.2). From these statistics, index threshold values were calculated.

Table 3.1 Example of Storm Data Collected For This Study

ID#	Location or County	Month	Day	Year	Time	Mag	Dth	Inj
1	JACKSON	2	10	1981	745	F2	0	2
2	PIKE	3	31	1981	1840	F2	0	0
3	COVINGTON	3	31	1981	2010	F2	0	2
4	MADISON	5	18	1981	2105	F2	0	1
5	MARSHALL	6	6	1981	230	F1	0	0
6	WARREN	6	6	1981	1700	F1	0	0
7	MARSHALL	9	13	1981	1645	F1	0	0
ID#	**Location or County**	**PrD**	**Length (miles)**	**Width (yards)**	**B-Lat**	**B-Long**	**E-Lat**	**E-Long**
1	JACKSON	250K	1	50	30.52	-88.55	30.52	-88.55
2	PIKE	250K	14	127	31.28	-90.43	31.35	-90.22
3	COVINGTON	250K	8	100	31.53	-89.52	31.55	-89.38
4	MADISON	250K	7	300	32.67	-89.93	32.65	-89.82
5	MARSHALL	25K	1	150	34.95	-89.63	34.95	-89.63
6	WARREN	3K	3	150	32.35	-90.75	32.37	-90.70
7	MARSHALL	3K	1	100	34.80	-89.58	34.80	-89.58

Table 3.2 Severe Weather Indices Studied (see appendix B for index definition)

Stability	Shear	Combination	Other
LI	SRH 0-2 km	SWEAT	LFC
SI	SRH 0-3 km	BRN	CCL
KI	BRN shear	EHI	LCL
CAPE			
CIN			
CAP			
Theta E			
TT			

Data Organization Methods

Tornado data were collected for all events occurring in the state of Mississippi from 1950-2000 (Table 3.1). Information in the database included the Mississippi county in which each tornado occurred, the date, time, F-scale rating, number of deaths, number of injuries, property damage (in dollars), path length, path width, beginning latitude and longitude and ending latitude and longitude of each tornado from 1950 to 2000. This information was collected from the NCDC and entered into Microsoft Excel spreadsheets. The tornadoes were then divided into three categories: weak, moderate, and strong. Tornadoes classified as weak were F0 and F1. Tornadoes classified as moderate were F2 and F3. Tornadoes classified as strong were F4 and F5.

Spatial Distribution

The database was then transferred into ArcView GIS and each tornado was plotted over a state map of Mississippi using each event's latitude and longitude coordinates. This was done in order to visualize the spatial distribution of the events (Figures 3.1, 3.2, 3.3). An attribute table was assigned to each tornado plot so that when a specific tornado is selected, a detailed description including the Mississippi county in which each tornado occurred, the date, time, F-scale rating, number of deaths, number of injuries, property damage (in dollars), path length, path width, beginning latitude and longitude and ending latitude and longitude of that tornado appears.

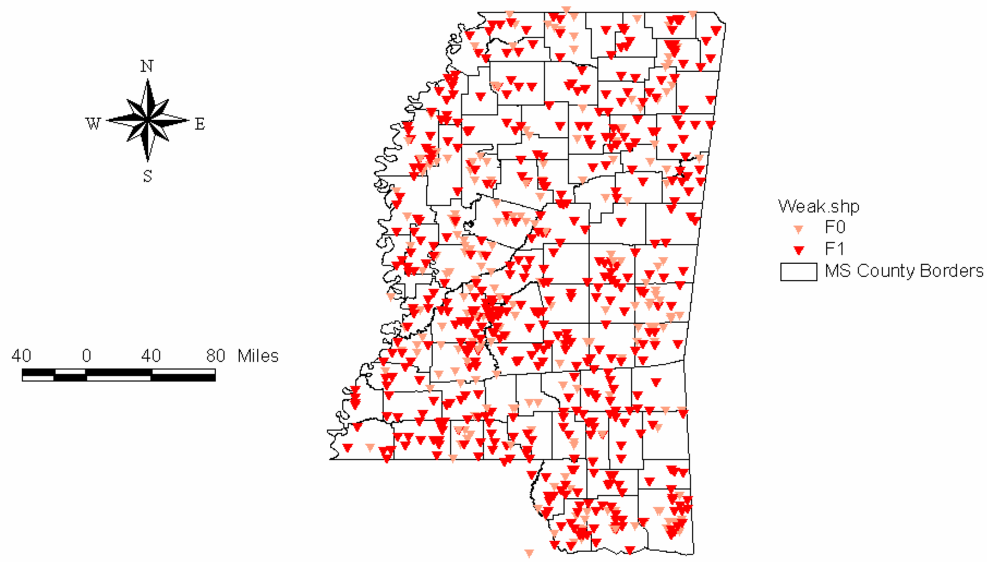

Figure 3.1 Spatial Distribution of Weak Tornadoes (F0, F1) for the state of Mississippi for 1950-2000

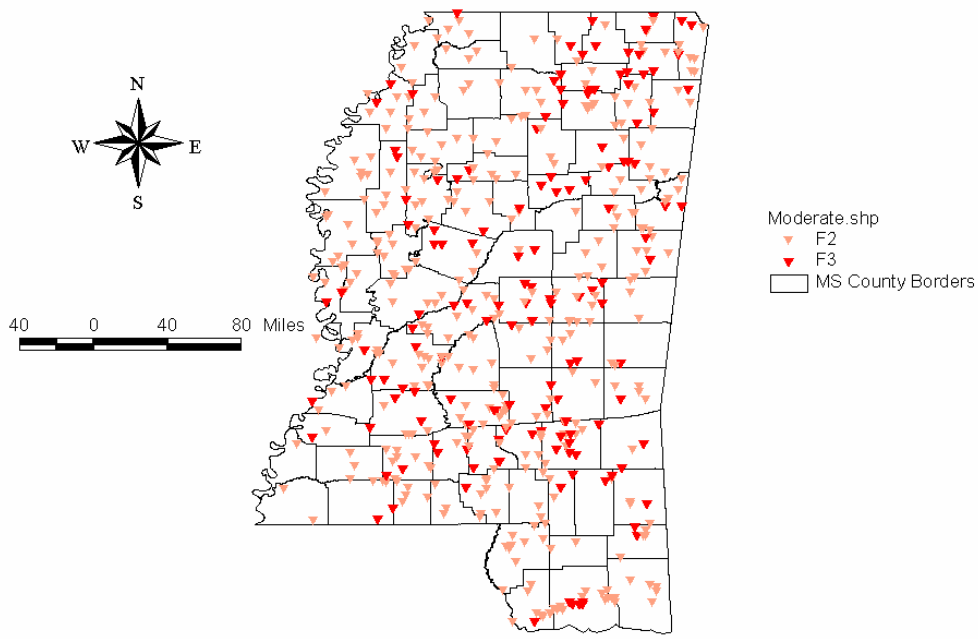

Figure 3.2 Spatial Distribution of Moderate Tornadoes (F2, F3) for the state of Mississippi for 1950-2000

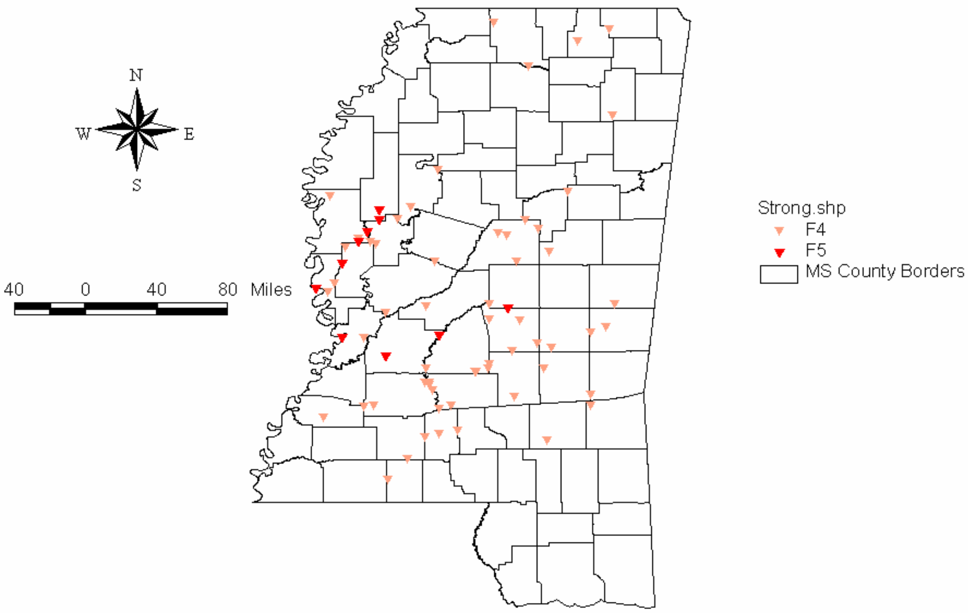

Figure 3.3 Spatial Distribution of Strong Tornadoes (F4, F5) for the state of Mississippi for 1950-2000

A cluster analysis was then performed on each of the three categories (Figures 3.4, 3.5, 3.6). This was done using the density function in ArcView GIS. The density function places a ten-mile radius around each tornado data point and where the radii overlap is where the highest density is displayed. The purpose of the cluster analysis was twofold. The first objective was to see if there was a population bias in the reporting of tornadoes. Since more people, hence more potential severe weather spotters, and better equipment exist in larger cities, it was believed that there would be a higher frequency of tornado reports around the larger cities. The second objective was to see if any other clusters of tornado reports existed that could not be attributed to population bias. Any of these clusters could then be further studied to determine what environmental factors exist in those affected areas to cause a higher frequency of tornadoes. Kelly et al. (1978) studied different regional characteristics of tornadoes and found two violent tornado maxima in Arkansas and Alabama (Figure 2.6). It is anticipated that this cluster analysis will highlight any consistent tornado maxima in Mississippi as well.

Temporal Distribution

Johns (1982) studied timing of severe weather outbreaks, including time of occurrence and duration for different regions of the United States. He found that differing environmental conditions across different regions directly affected timing of severe weather outbreaks. In this study, tornado frequency was plotted by decade, season, month, time of day, hour of day, and F-scale rating in graphs created using Microsoft Excel from the storm database (Figure 3.7, 3.8, 3.9, 3.10, 3.11, 3.12)

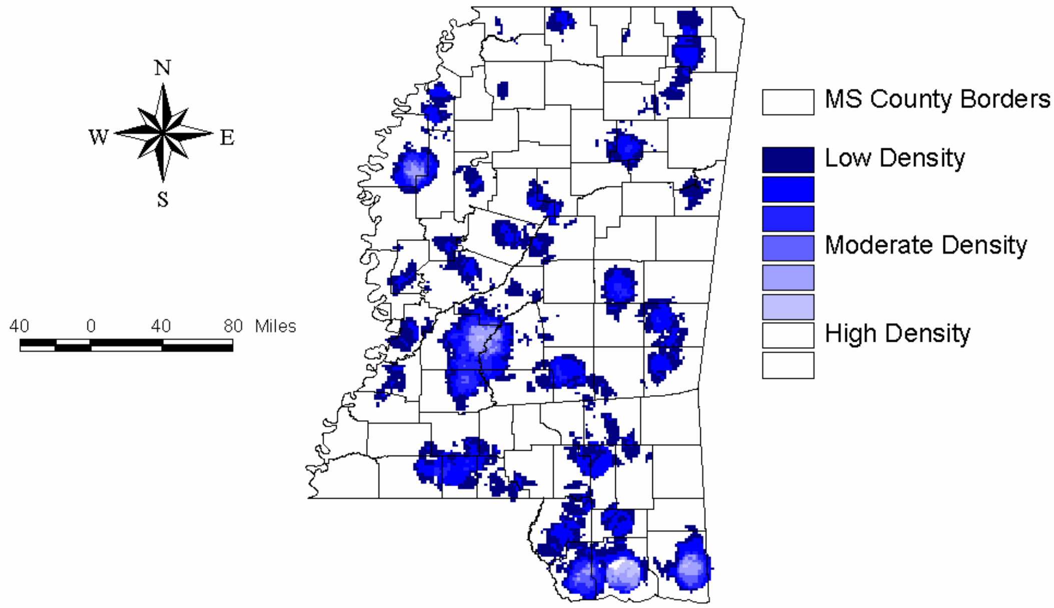

Figure 3.4 Density of Weak Tornadoes (F0, F1) for the state of Mississippi for 1950-2000

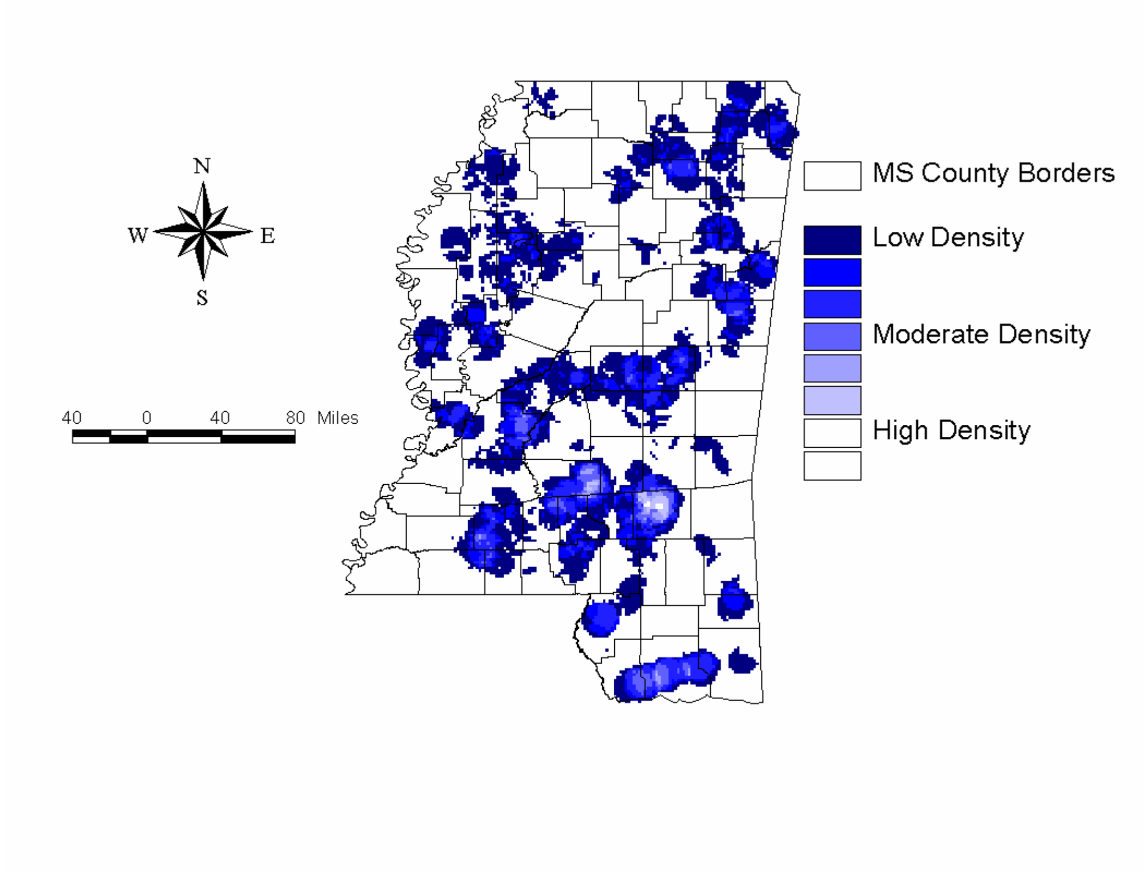

Figure 3.5 Density of Moderate Tornadoes (F2, F3) for the state of Mississippi for 1950-2000

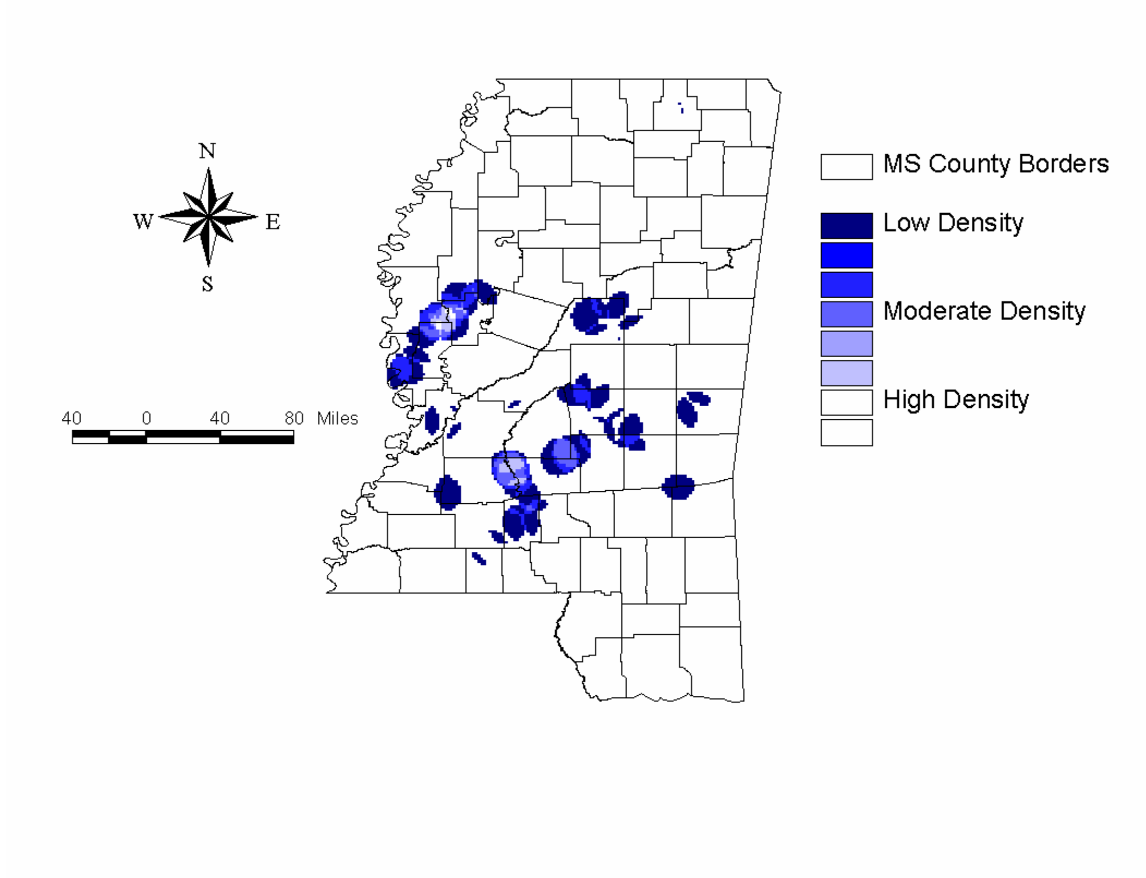

Figure 3.6 Density of Strong Tornadoes (F4, F5) for the state of Mississippi for 1950-2000

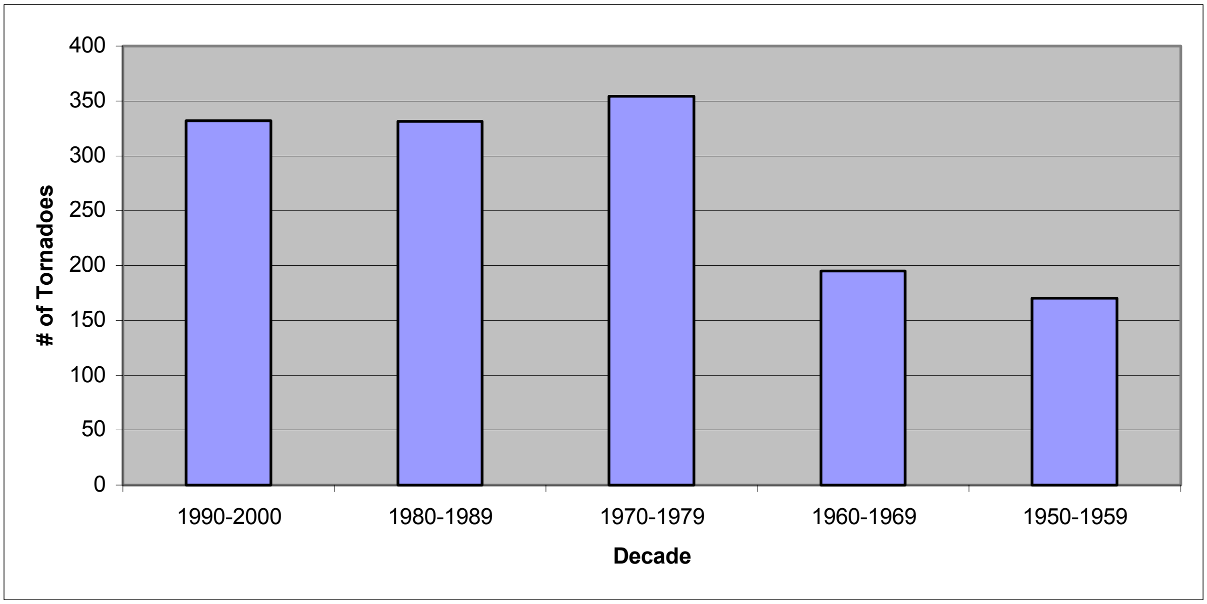

Figure 3.7 Tornado Frequency Per Decade

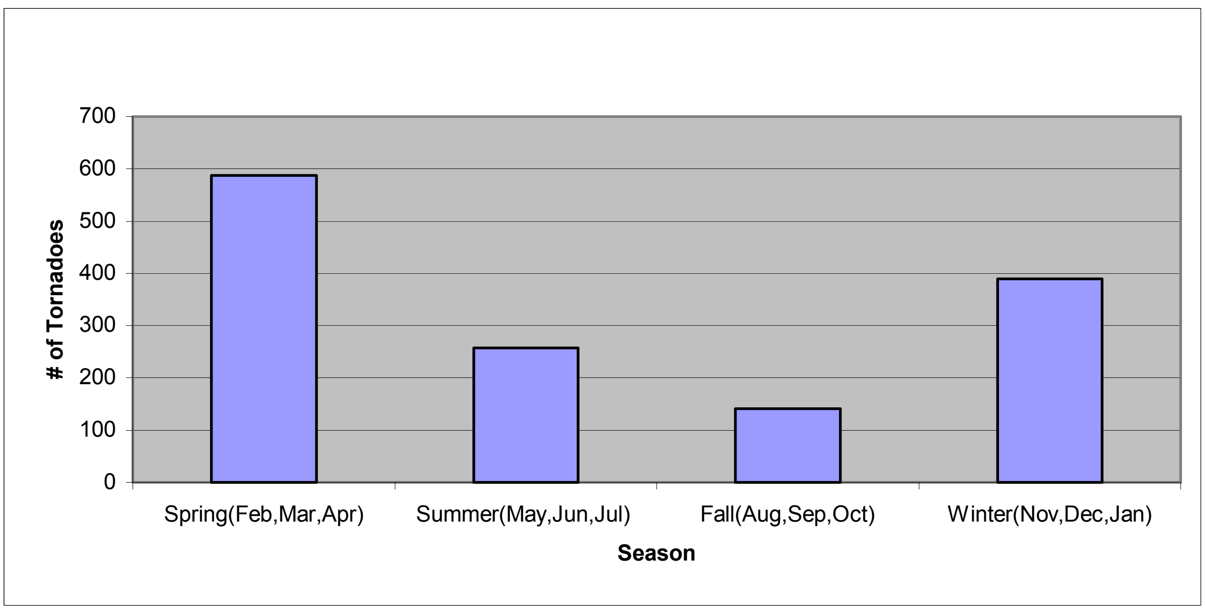

Figure 3.8 Tornado Frequency Per Season

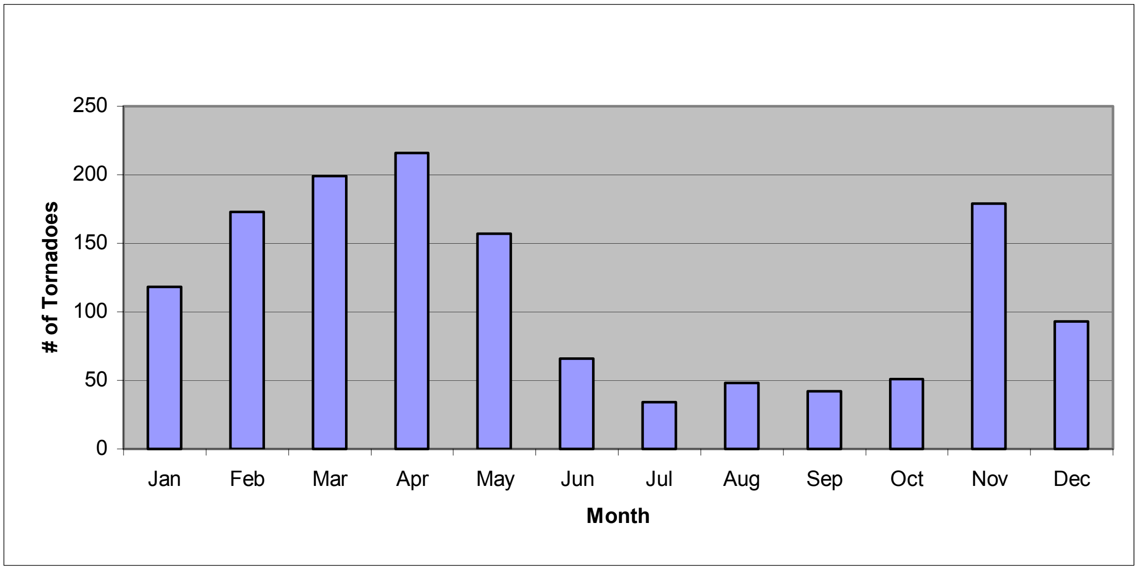

Figure 3.9 Tornado Frequency Per Month

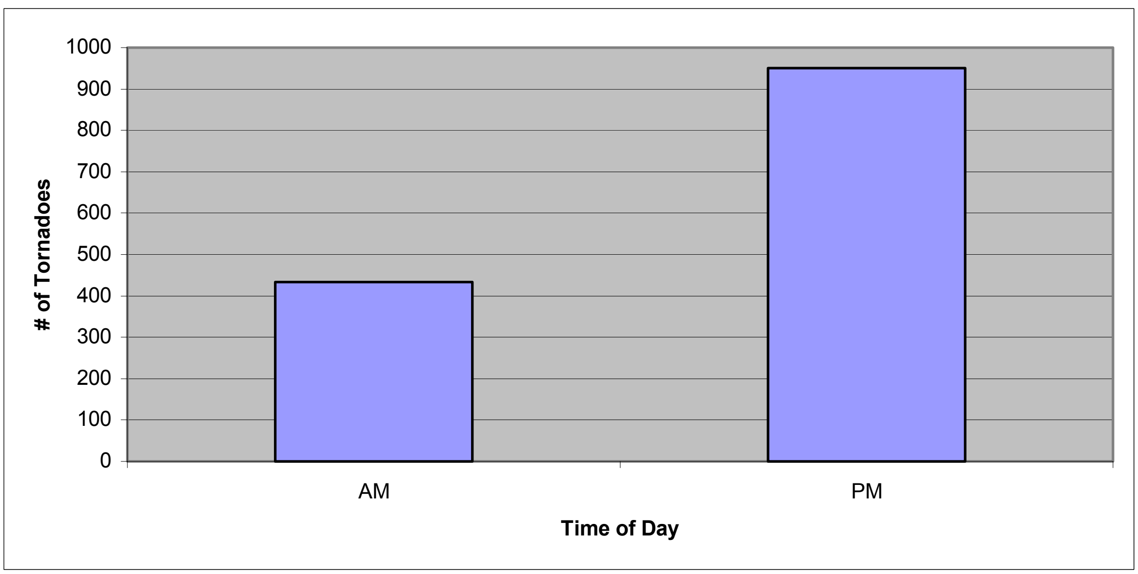

Figure 3.10 Tornado Frequency Per Time of Day

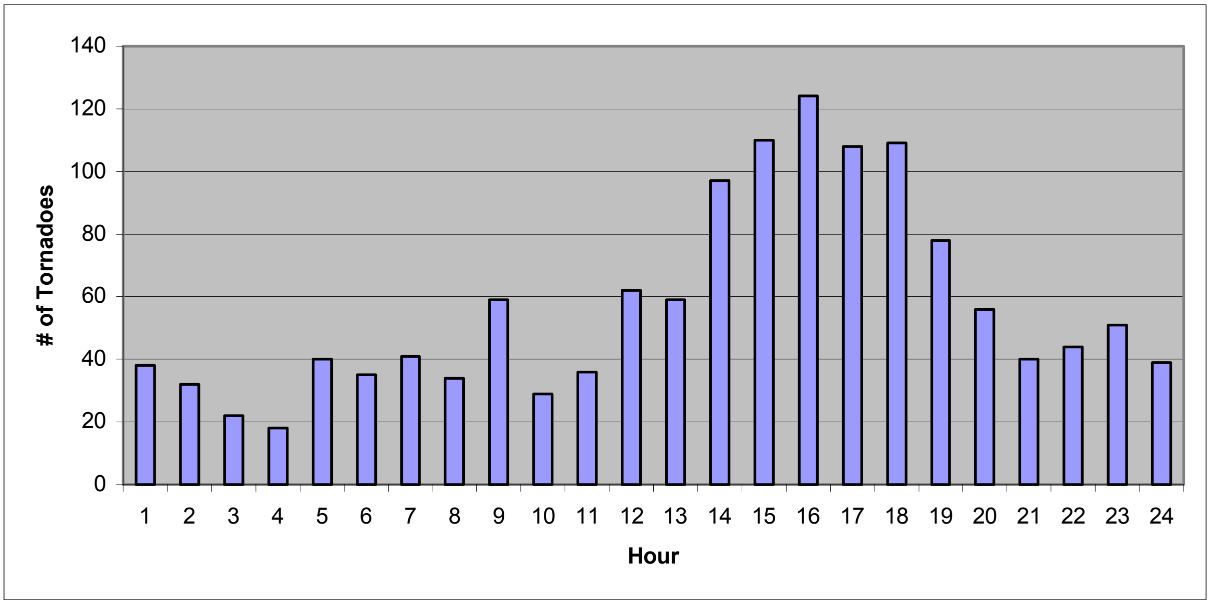

Figure 3.11 Tornado Frequency Per Hour of Day

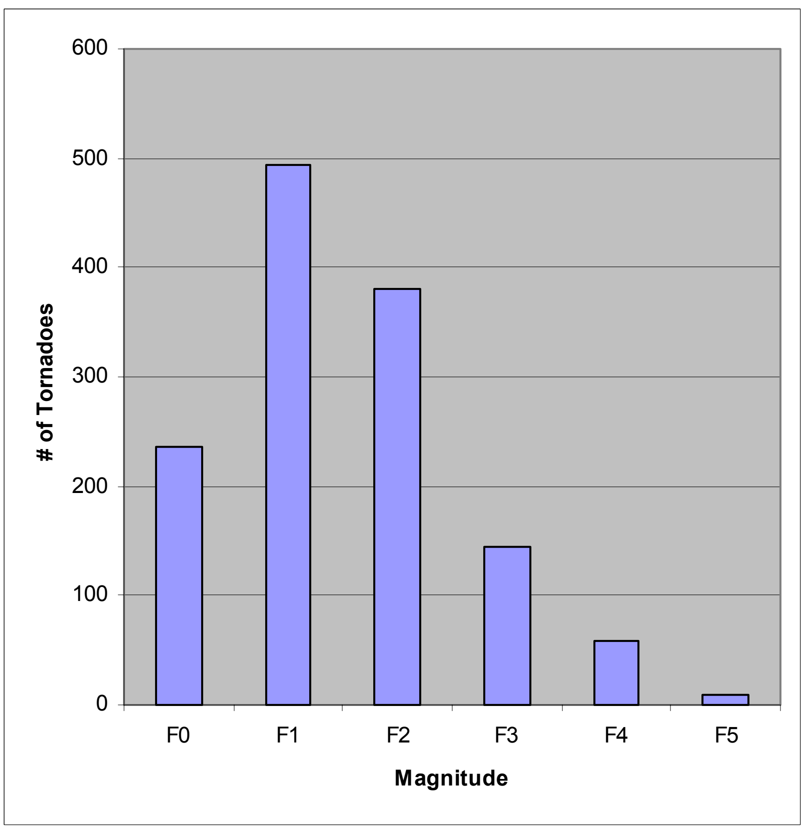

Figure 3.12 Tornado Frequency Per F-scale Rating

One anticipates that tornado report frequency will be highest in the later decades due to increased technology and public awareness, and will also be highest in the afternoon hours in the Spring months due to daytime heating and increased differences in colliding air masses. It is also anticipated that there will be more reports of weak tornadoes than moderate and strong ones.

Thermodynamic Analysis

Due to time restrictions and database size, only ten percent of the tornadoes were analyzed in the thermodynamic study. There were a total of 1387 tornadoes in the database, therefore roughly 138 tornadoes were needed for the thermodynamic study. A representative subset was selected based on the temporal distributions. First, calculations were performed to determine what percentage of tornadoes occurred in each decade, season, month, time/hour of day, and F-scale category. Then, a final total of 137 tornadoes were chosen to reflect the same percentages from each decade, season, month, time/hour of day, and F-scale category. The problem of tornado days, where several tornadoes occurred within the same outbreak in close timing and proximity to one another, were used to further stratify the data. Only one tornado from each tornado day was chosen for the thermodynamic study in order to avoid potential bias toward a certain atmospheric setup that occurred on those particular days. Once the selected tornadoes for the thermodynamic study were entered into a separate database, RAOB data were collected from the physically and temporally closest Skew-T data available from either the Jackson, MS or Little Rock, AR National Weather Service balloon launch sites.

The thermodynamic data were entered into a subset database that could be compared to a representatively similar database (Brown, 2002) collected from the Great Plains region (northern Texas, Oklahoma, and Kansas) of the United States to determine any differences between index threshold values between these two regions. The Great Plains data set was chosen to as closely match the Mississippi data set as possible as far as tornado strength, season of occurrence, and so forth.

Several indices were chosen to be compared between the two data sets. Nine matching thermodynamic indices were available for both the Mississippi data set and the Great Plains data set. Stability indices studied included: LI, CAPE, CAP and TT. Shear indices studied included: SRH 0-2km and BRN shear. Combination indices studied included: SWEAT, BRN and EHI. Definitions of these indices can be found in Appendix B.

Each of these indices was chosen to assess specific aspects of severe weather environments including atmospheric energy, wind direction and speed shear, temperature, moisture, and lift. Sample means were then calculated and two-tailed t-tests were run to determine any significant differences between the sample means. Significant differences suggest the tornadoes occurred in different environments, all else being equal (tornado strength and season of occurrence for example).

Chapter IV

RESULTS AND DISCUSSION

Spatial Distribution

Several cluster patterns were identified using ArcView GIS. Population bias is evident when analyzing the weak, moderate, and strong density distributions. Clustering occurs around metropolitan areas and highways and interstates. An increase in the reports of tornadoes was expected in these areas due to an increase in spotter networks and technology centers.

The weak tornado density distribution shows a potential population bias near the Jackson metropolitan area and the Mississippi Gulf Coast (Figure 3.4). There is another identifiable cluster in the historical Delta region of the state, which will be mentioned later in this discussion. The moderate tornado density distribution also shows a potential population bias (Figure 3.5). Not only are the Jackson metropolitan area and Gulf Coast identifiable with respect to tornado clustering, but also areas near Interstate 20 from Jackson to Meridian and Highway 45 from Meridian to Tupelo. The strong tornado density distribution shows some population bias near the Jackson metropolitan area, but most significantly it shows an identifiable cluster along the southern edge of the historical Delta region near the previously mentioned weak tornado cluster (Figure 3.6).

There are several possible reasons for this strong tornado cluster including terrain and increased moisture. The terrain in this area is unlike any other area in the state in that there are bluffs along the floodplain of the Mississippi River that separate low elevation, flat land to the West of the bluffs from higher elevation land to the East of the bluffs. There may also be an increase in moisture in this area due to it being the floodplain of the Mississippi River and well-irrigated cropland. It is unclear as a result of this study what direct effect the historical Delta region of Mississippi has on the formation and potential clustering of tornadoes, therefore this area warrants further study.

Temporal Distribution

The temporal distributions (Figures 3.7, 3.8, 3.9, 3.10, 3.11, 3.12) followed expectations. Due to increased public interest and awareness and improved technology such as Doppler radar, tornado report frequency was greater in the latter half of this study than in the beginning half (Figure 3.7). There are two apparent seasonal maxima in Mississippi, the greatest being in the spring February, March, and April and the second being in the winter, particularly November, due to increased differences in colliding air masses (Figures 3.8 and 3.9). Due to daytime heating the majority of tornadoes occurred in the afternoon hours, particularly between 3pm-6pm (Figures 3.10 and 3.11). Also as expected, there were more weak and moderate tornadoes reported than there were strong tornadoes (Figure 3.12).

Thermodynamics

Table 4.1 displays the nine indices that were tested between the Mississippi and Great Plains data set and their means, t values, p values and any significance that was found using a two-tailed t-test. LI, TT, CAPE, SWEAT and EHI were all found to be significantly different at alpha of 0.01 between the Mississippi and Great Plains data set, meaning that this study is ninety-nine percent confident that tornadoes form in significantly different environments between the two regions with respect to these indices. A significant difference at alpha of 0.05 for 0-2km SRH was found between the Mississippi and Great Plains data set, meaning that this study is ninety-five percent confident that tornadoes form in significantly different environments between the two regions with respect to this index. BRN Shear, BRN and CAP were not found to be significantly different at alpha of 0.01 or alpha of 0.05 between the Mississippi and Great Plains data set, meaning that this study did not find that tornadoes form in significantly different environments between the two regions with respect to these indices. It can be concluded that temperature and moisture profiles differ for the development of tornadoes between the two regions, whereas wind profiles and capping effect do not differ as greatly between the two regions. This may be attributed to southerly winds bringing moisture from the Gulf of Mexico to the Mississippi region but a more dry, hot air mass over the Great Plains.

Table 4.2 displays the means of the thermodynamic indices calculated and compares the accepted threshold values currently used where applicable. The purpose of Table 4.2 is to give forecasters a severe weather check sheet to compare Mississippi tornadoes to currently used threshold values derived from other studies.

Table 4.1 Severe Weather Indices Tested Between Mississippi and the Great Plains

Index	MS Mean	GP Mean	T Value	P Value	Significance
LI	-0.223	-6.964	-7.859	7.35E-13	**
TT	45.025	53.385	5.286	5.89E-07	**
CAPE	602.919	2369.769	10.253	5.71E-19	**
SWEAT	269.330	370.446	4.234	4.01E-05	**
EHI	0.526	2.026	7.309	1.55E-11	**
0-2km SRH	99.775	159.744	2.452	0.016	*
BRN Shear	8.083	8.277	0.237	0.813	
BRN	63.688	44.641	-0.567	0.572	
CAP	1.201	1.179	-0.083	0.934	

* indicates significance at $p < 0.05$
** indicates significance at $p < 0.01$

Table 4.2 Severe Weather Index Comparison Between Mississippi and the Great Plains

	MS Mean	Currently used threshold values (where applicable)
LFC	1464.432	N/A
CCL	1591.342	N/A
LCL	1045.099	N/A
SWEAT	269.330	SWEAT of 150-300 Supercells possible SWEAT of 300-400 Severe supercells possible SWEAT of 400+ Tornadic supercells possible
CAP	1.201	CAP > 2 Generally prevents t-storm Development
LI	-0.223	LI > +4 Stable atmosphere LI of 0 to +3 Slightly unstable atmosphere LI of -1 to -4 Marginally unstable atmosphere LI > -5 Largely unstable atmosphere
TT	45.025	TT < 44 No convection TT of 44-50 Convection likely with a few moderate thunderstorms TT of 51-52 Isolated severe thunderstorms TT > 53 Scattered to numerous severe t-storms with tornadoes possible
KI	24.950	KI < 15 No convection – <10% probability KI of 15-25 Convection possible – 20-40% probability KI of 26-39 Convection likely – 50-80% probability KI of 40+ Convection – 90-100% probability
SRH 0-3km	151.333	SRH of 150-300 Supercells possible SRH of 300-400 Severe supercells possible SRH of 400+ Tornadic supercells possible
SRH 0-2km	99.775	SRH of 150-300 Supercells possible SRH of 300-400 Severe supercells possible SRH of 400+ Tornadic supercells possible
CAPE	602.919	CAPE of 1-1500 Positive – weak convection CAPE of 1500-2500 Large Positive – moderate convection CAPE of 2500+ Extreme Positive – strong Convection

Table 4.2 cont. Severe Weather Index Comparison Between Mississippi and the Great Plains

CIN	-43.613	CIN < 15 CIN of 15-20 CIN of 50-150 CIN > 200	Fair weather cumulus and CIN overcome easily Few strong thunderstorms possible if CIN is overcome Strong lines of thunderstorms possible if CIN is overcome Indicates strong cap and no t-storm development likely because CIN is very difficult to overcome
BRN	63.688	BRN > 40 BRN 10-40 BRN < 10	Supercells Optimum for severe storms Environment too sheared
EHI	0.526	EHI > 1 EHI of 1-5 EHI 5+	Supercells likely F2/F3 tornadoes possible F4/F5 tornadoes possible
Theta E	330.823	N/A	
BRN Shear	8.083	N/A	
SI	1.148	SI > +4 SI of 0 to +3 SI of -1 to -4 SI of -5 to -7 SI < -8	Stable atmosphere Slightly unstable atmosphere Marginally unstable atmosphere Largely unstable atmosphere Very unstable atmosphere

Chapter V

SUMMARY AND CONCLUSIONS

Summary

Mississippi leads the nation in tornado related deaths per million people with a total of one-hundred and sixty-six deaths between the years of 1953 and 1995, and ranks very high in other tornado related categories such as total tornado related deaths, number of killer tornadoes, and number of annual tornadoes per ten thousand square miles (Grazulis, 1995). However, most tornado research is still performed in the Great Plains region of the United States even though recent studies suggest that tornadoes develop in different environments in different regions of the country (Davis et al., 1997). Therefore it is important to study and understand tornado development in different regions of the country, particularly Mississippi.

The tornado data for this research were taken from the National Climate Data Center for the years 1950-2000. Parameters collected for the spatial and temporal distribution portions of this study included the Mississippi county in which each tornado occurred, the date, time, F-scale rating, number of deaths and injuries, property damage (in dollars), path length and width, and beginning and ending latitude and longitude of each tornado. For the thermodynamic portion of this study only ten percent of the tornadoes from 1958-2000 were studied due to the size of the database, time limitations, and the existence of less reliable data prior to 1960.

Severe weather indices collected for the thermodynamic study included LI, SI, KI, CAPE, CIN, CAP, Theta E, TT, SRH 0-2km, SRH 0-3km, BRN shear, SWEAT, BRN, EHI, LFC, CCL and LCL, all taken from Jackson, MS and Little Rock, AR RAOB data. Definitions for each of the indices can be found in appendix B. These indices were chosen in order to analyze the stability of the atmosphere surrounding the tornado events through temperature, moisture and wind profiles.

Conclusions

The spatial distribution of Mississippi tornadoes revealed several cluster patterns that were identified using ArcView GIS. Many of the clusters could be attributed to population bias, but the historical Delta region in Northwest Mississippi exhibited a cluster pattern for tornadoes that could not be explained through population bias. Therefore it can be assumed that unique environmental factors, such as topography (the bluffs along the floodplain of the Mississippi River) and increased moisture (due to the floodplain of the river and soil moisture from cropland) may influence the development of tornadoes in this region of the state.

The temporal distribution showed an increase in tornado frequency during the latter half of this study due to increased public awareness and improved technology. It also revealed increased frequency of tornadoes during the spring and early winter when colliding air masses differ the most, and during the late afternoon hours due to daytime heating. The temporal analysis showed a higher frequency of weak tornadoes than moderate and strong tornadoes.

Several thermodynamic indices were proven to be statistically different between Mississippi tornadoes and tornadoes in the Great Plains region of the United

States, all else being equal. These indices included LI, TT, CAPE, SWEAT, EHI and 0-2km SRH. Therefore, it can be concluded that temperature and moisture profiles differ for the development of tornadoes between the Mississippi region and the Great Plains region studied most likely due to southerly winds bringing in moist heat over Mississippi, while the same winds bring a more dry heat over the Great Plains region.

A major limitation of this study involved the thermodynamic portion. Due to the large number of tornadoes that occurred in Mississippi from 1950-2000 (1387) and the limited amount of time available for this study, only ten percent of the tornadoes were selected to be examined for the thermodynamic analysis. Since the database has now been established (a very time-consuming task) future research could examine a larger percentage of the tornadoes for a more complete look at the thermodynamic properties surrounding the tornado events. Also, the tornado cluster identified in the historical Delta region of Mississippi could not be exhaustively studied. This spatial aspect of tornadic activity in Mississippi deserves further investigation.

The information collected and examined in this study should be of great use to operational forecasters. Table 4.2 provides a "handbook" of thermodynamic index values indicating potential tornado formation in Mississippi. The study provides a sound basis for future studies to be conducted and provides forecasters a better idea of where and when to look for tornado development in Mississippi by categorizing threat levels shown by thermodynamic parameters unique to Mississippi tornado events.

APPEDIX A

FUJITA SCALE

Fujita Scale

Scale	Wind Estimate in MPH	Typical Damage
F0	<73	Light Damage: Some damage to chimneys; branches broken off trees; shallow-rooted trees pushed over; sign boards damaged.
F1	73-112	Moderate Damage: Peels surface off roofs; mobile homes pushed off foundations or overturned; moving autos blown off roads.
F2	113-157	Considerable Damage: Roofs torn off frame houses; mobile homes demolished; boxcars overturned; large trees snapped or uprooted; light-object missiles generated; cars lifted off ground.
F3	158-206	Severe Damage: Roofs and some walls torn off well-constructed houses; trains overturned; most trees in forest uprooted; heavy cars lifted off the ground and thrown.
F4	207-260	Devastating Damage: Well-constructed houses leveled; structures with weak foundations blown away some distance; cars thrown and large missiles generated.
F5	261-318	Incredible Damage: Strong frame houses leveled off foundations and swept away; automobile-sized missiles fly through the air in excess of 100 meters (109 yards); trees debarked; incredible phenomena will occur.

Source: http://www.spc.noaa.gov/faq/tornado/f-scale.html

APPENDIX B

THERMODYNAMIC PARAMETERS

BRN stands for Bulk Richardson Number and can be found by dividing CAPE by the 0-6km shear.

BRN < 45	Supercells
BRN in the Teens	Optimum for severe storms
BRN < 10	Environment too sheared

CAP is given in degrees Celsius and if strong enough, generally above 2, will prevent thunderstorm development.

CAPE stands for Convective Available Potential Energy and is the positive area, between the parcel and environmental temperature, on a Skew-T sounding.

CAPE of 1-1500	Positive – weak convection
CAPE of 1500-2500	Large Positive – moderate convection
CAPE of 2500+	Extreme Positive – strong convection

CCL is the level at which condensation will occur if a parcel rises adiabatically and reaches saturation due to heating from below.

CIN stands for Convective Inhibition and is the opposite of CAPE, or the negative area on a Skew-T sounding. High values of CIN indicate stability of the atmosphere.

CIN < 15	Fair weather cumulus and CIN overcome easily
CIN of 15-20	Few strong thunderstorms possible if CIN is overcome
CIN of 50-150	Strong lines of thunderstorms possible if CIN is overcome
CIN > 200	Indicates strong cap and no thunderstorm development likely because CIN is very difficult to overcome

EHI stands for Energy Helicity Index and can be found by multiplying SRH by CAPE and dividing this number by 160,000.

EHI > 1	Supercells likely
EHI of 1-5	F2/F3 tornadoes possible
EHI 5+	F4/F5 tornadoes possible

KI stands for K Index and can be found by subtracting the temperature at 500mb from the temperature at 850mb and subtracting the dewpoint depression at 700mb from the dewpoint at 850mb and adding these two numbers together.

KI < 15	No convection – <10% thunderstorm probability
KI of 15-25	Convection possible – 20-40% thunderstorm probability
KI of 26-39	Convection likely – 50-80% thunderstorm probability
KI of 40+	Convection – 90-100% thunderstorm probability

LCL stands for Lifted Condensation Level and is the level of convective cloud formation due to forced lifting.

LFC stands for Level of Free Convection and is the level at which a parcel becomes unstable and will begin to rise.

LI stands for Lifted Index and is found by subtracting the 500mb parcel temperature from the 500mb environmental temperature.

LI > +4	Stable atmosphere
LI of 0 to +3	Slightly unstable atmosphere – showers
LI of -1 to -4	Marginally unstable atmosphere – thunderstorms
LI > -5	Largely unstable atmosphere – severe thunderstorms

SI stands for Showalter Index and is found by subtracting the 850mb parcel temperature from the 850mb environmental temperature.

SI > +4	Stable atmosphere
SI of 0 to +3	Slightly unstable atmosphere – showers
SI of -1 to -4	Marginally unstable atmosphere – thunderstorms
SI of -5 to -7	Largely unstable atmosphere – severe thunderstorms
SI < -8	Very unstable atmosphere – severe thunderstorms and possible tornadoes

SRH stands for Storm Relative Helicity.

SRH of 150-300	Supercells possible
SRH of 300-400	Severe supercells possible
SRH of 400+	Tornadic supercells possible

SWEAT stands for Severe Weather Threat Index and helps determine whether or not a thunderstorm will be severe by taking into account not only moisture and instability, but also vertical wind velocities or shear.

SWEAT of 150-300	Supercells possible
SWEAT of 300-400	Severe supercells possible
SWEAT of 400+	Tornadic supercells possible

Theta-E stands for Equivalent Potential Temperature and is the temperature of a parcel of air after it is brought to the 1000mb level and has released all of its latent heat.

TT stands for Total Totals Index and is found by subtracting the temperature at 500mb from the temperature at 850mb and subtracting the temperature at 500mb from the dewpoint at 850mb and adding these two numbers together.

TT < 44	No convection
TT of 44-50	Convection likely with a few moderate thunderstorms
TT of 51-52	Isolated severe thunderstorms
TT > 53	Scattered to numerous severe thunderstorms with tornadoes possible

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